

FINAL REPORT: 07/01/2005 - 06/30/2007

Forecasts that Communicate: Assessment, Development, and Delivery of Probabilistic Forecasts that Foster Easy, Accurate, and Reliable Interpretation

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Program Element: Climate and Societal Interactions, Human Dimensions of Global Change Research

Project Number: NA05OAR4311125

Project Description

The primary objective of this project is to improve the ease, accuracy, and reliability with which seasonal forecast products are interpreted. Supporting objectives are to:

- Foster ongoing, iterative relationships between research, operational forecasting, and water management communities.
- Enable the efficient provision of customizable forecast formats by operational forecasters or information intermediaries (e.g., extension agents).
- Provide feedback tools to the operational forecasting and social science community to track forecast formats and elements preferred by diverse stakeholders.
- Improve water managers' perceptions of climate forecast credibility, through more accurate understanding of the contents of forecast products.

Our project focuses on two components. The first is to quantitatively assess multiple forecast formats for easy, reliable, and correct interpretation. From this effort we hope to identify specific product elements that consistently improve (or confound) forecast communication, which can then be applied to (or eliminated from) a broad range of forecast products. The second component of our proposed work is the implementation of dynamically interactive Internet-based webtools that will allow users to customize a forecast product to best fit their cognitive style, technical capabilities, and decision making needs.

Project Activities

Field Assessment of Forecast Formats

We developed a collection of various seasonal forecast products issued using different formats, focusing on official products from the National Weather Service (NWS) Climate Prediction Center (CPC), International Research Institute for Climate and Society (IRI), Environment Canada, and Australian Bureau of Meteorology. We also developed several alternatives to these products, focusing on alternative terminology and supporting interpretive graphics (e.g., bar charts, pie charts, regional scale indicators). While we

focused on tercile-based products, we also included CPC Probability of Exceedance (POE) plots.

Working with Niina Haas, Assistant Staff Scientist in the Core Office of the University of Arizona's (UA) Climate Assessment for the Southwest (CLIMAS) project, we developed a series of formal survey instruments. The questionnaires were pre-tested using several volunteers within CLIMAS and the UA Institute for the Study of Planet Earth (ISPE). Survey questions focused on the respondent's existing familiarity and use of climate forecasts, and comprehension of a single forecast product. Questions were identical across questionnaires, or as similar as possible consistent with the specific product format. Questions were targeted toward determining whether respondents could correctly:

- identify the variable depicted (e.g., temperature, temperature anomaly, probability, probability anomaly),
- identify the forecast categories (e.g., above and below median, terciles),
- identify the forecast reference period,
- identify probability ranges,
- identify situations lacking forecast opportunity,
- identify the appropriate spatial scale,
- translate forecast information into alternative terminology, and
- extend forecast information to related concepts (e.g., statistical meaning).

We coordinated with two professional societies to implement the survey protocol at their annual meetings. The protocol consisted of distributing a survey to each meeting participant in a pseudo-random order, with a small fraction of people being asked to complete their survey in an interview setting. The goal was 100% distribution of the surveys, with enough returns to assess the statistical significance of results for each question. Each person was asked to complete a single survey, precluding learning of forecast concepts across multiple products. The interviews consisted of the respondent answering the questions on the survey, in the presence of an interviewer, while also being prompted to explain why they selected specific answers or how they determined a specific answer.

Our first field survey was conducted at the Annual Meeting of the American Water Resources Association (AWRA), 7-10 November 2005, in Seattle, WA. This meeting involved about 475 participants who attended sessions on diverse water resources management topics. Our second survey was conducted at the Annual Meeting of the American Meteorological Society (AMS), 29 January – 2 February 2006, in Atlanta, GA. This meeting involved several thousand participants who attended sessions on many aspects of meteorology, climatology, and hydrology.

Both organizations were cooperative in allowing the surveys to be administered. However, the AWRA meeting style and size was much more successful. At the AWRA meeting, we were allowed to set up a table near registration for the entire meeting, from which we could personally hand out and request returns from meeting participants at every break throughout the meeting. At the AWRA meeting, we received nearly 150 completed questionnaires and completed interviews for each forecast product. At the

AMS meeting, we were allowed to place a stack of surveys at each registration booth and have a survey return box nearby. However, the AMS meeting registration is so busy and distracting to participants, that almost no one saw or took the surveys. We then placed surveys at key locations (e.g., near the email access and daily newsletter distribution sites) throughout the week, but very few surveys were picked up by participants. Upon questioning several participants, it became clear that people were distracted by other meeting activities and didn't see the surveys. We received fewer than two dozen returned surveys from the AMS meeting.

Key Results:

- A meeting the size of the AMS Annual Meeting is too big for effective survey administration. There are too many distractions for attendees to notice surveys placed at the registration counters. A meeting the size of the AWRA Annual Meeting allows personal distribution of surveys, although with significant effort throughout the meeting to solicit survey returns. The return rate from the AWRA meeting would have been lower without the 'hustle and harass' approach.
- Respondents at the AWRA meeting had high potential for considering climate variability, but the current forecast formats discourage people from engaging with the product. This is exemplified by interview comments saying, in essence, "This product must not be applicable to my work, because otherwise I would understand it."
- Current forecast products are being extensively misinterpreted. Experienced forecast users had more incorrect answers than non-users.
- No forecast format was more effective than any other, but the POE format, as currently delivered by the CPC, is notably ineffective. The only effective alternative format of those tested was the highly simplified POE product.
- The major forecast format issues are (1) complexity without clear structure and (2) persistent language problems (e.g., the use of 'above' and 'below' with regard to tercile forecast categories, and identifying when forecasts of opportunity are not warranted).

Key findings:

- Information itself, within a forecast product, is insufficient. People have trouble coordinating and connecting information, and disconnected product elements create confusion.
- People are confused and tentative about basic statistical principles.

Recommendations:

- A forecast product should structure a person's interaction with the information.
- A forecast product should have explicit reinforcement of basic principles of statistics and probability.

Improving Interpretation and Formats of Operational Forecast Products

Through this project, we began working with the Climate Services Division (CSD) of the Office of Weather, Water, and Climate Services, National Weather Service (NWS) in training NWS Weather Forecast Office (WFO) personnel about forecast interpretation and communication, as part of the CSD Climate Operations Training Course. Material in that course was based in part on findings from the surveys and interviews in this project.

By the end of this project, at least one person from each of the 122 WFOs had received training in correctly interpreting the seasonal climate outlooks.

Based on our survey results from the AWRA meeting, CSD requested assistance in the design of their experimental Local 3-Month Temperature Outlook (L3MTO). We worked with the L3MTO design team, including their website development contractors, to develop multiple formats of the local version of the Climate Prediction Center (CPC) seasonal climate outlook. In particular, our work resulted in using a pie chart format, two versions of a simplified probability of exceedance plot, tabular formats that allowed users to specify a confidence interval and obtain a corresponding range of forecast values, and text forecasts that required no interpretation on the part of users. An experimental version of one format is shown in Figure 1. Figure 2 shows the variety of formats that eventually became the operational L3MTO product. The probability of exceedance plots allow a user to choose among several confidence levels and the temperature range narrows or contracts accordingly, thus reinforcing that forecasts for a narrow range of conditions cannot be made with a high degree of confidence.

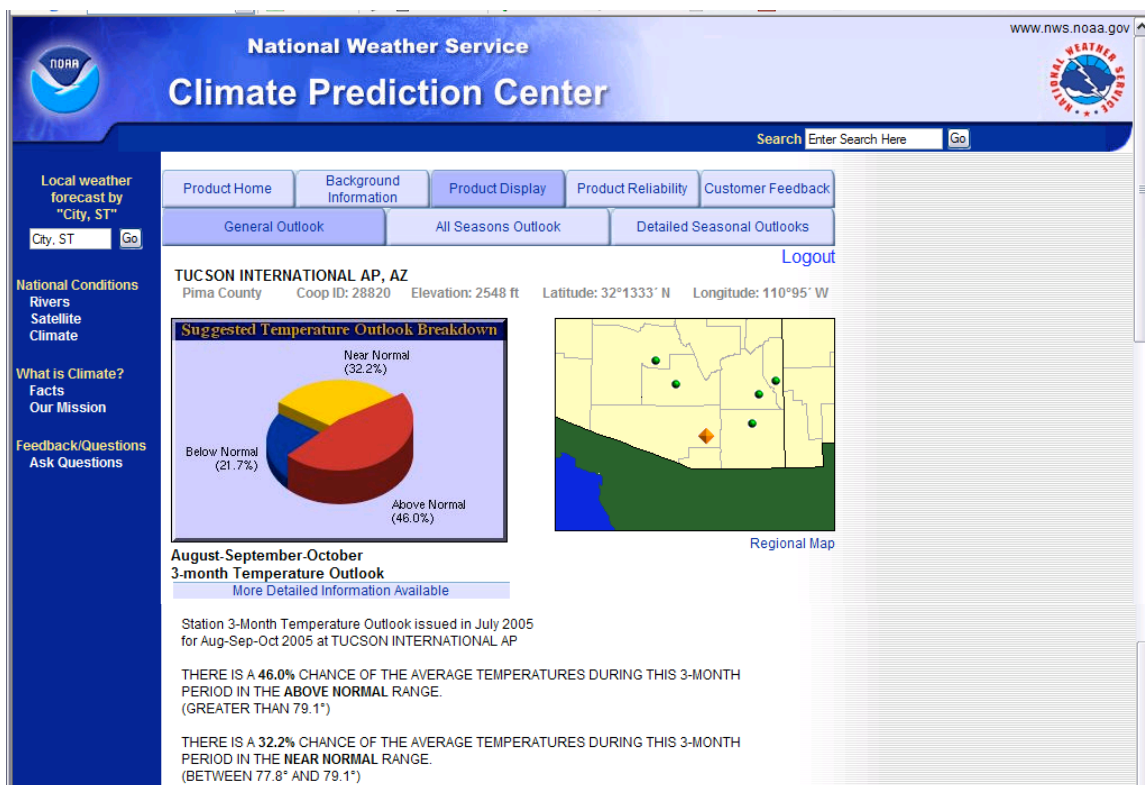


Figure 1. Experimental version of NWS Local 3-Month Temperature Outlook using pie chart and quantitative text statements.

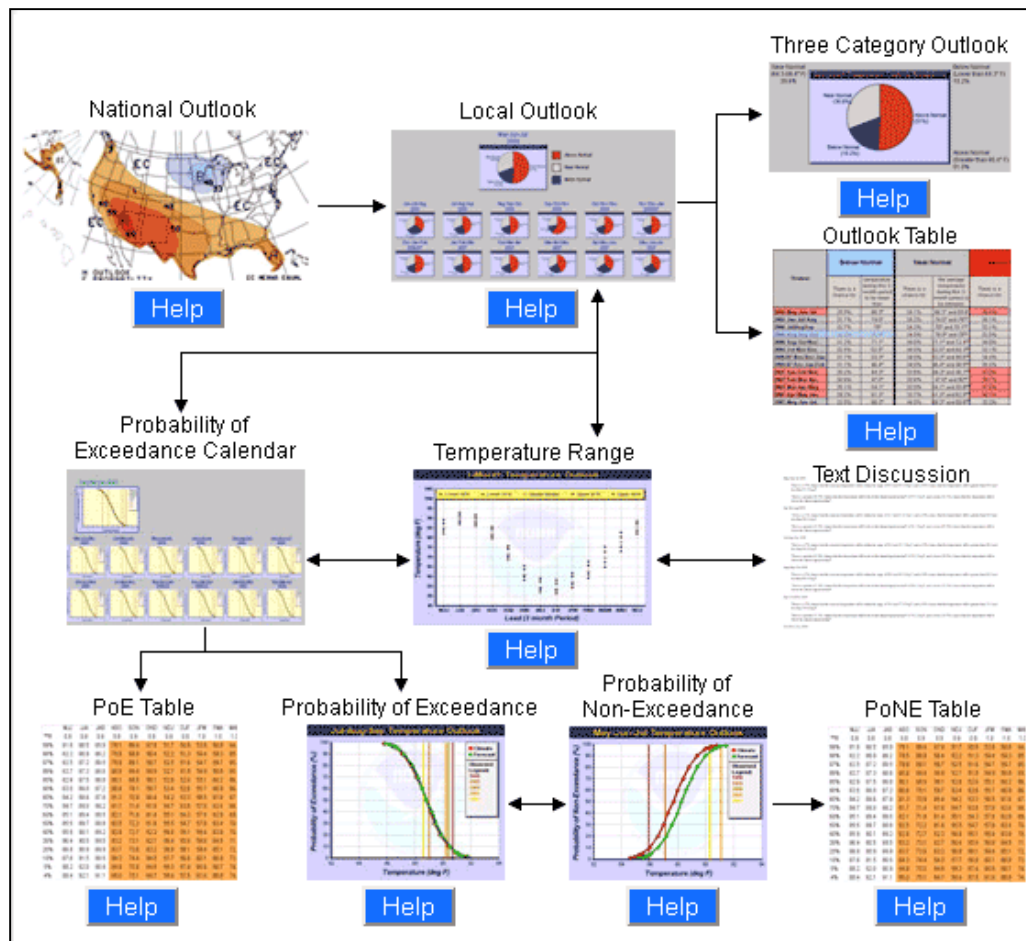


Figure 2. The variety of formats incorporated in the L3MTO product enables users to select the product most aligned with their cognitive framework and information specificity needs.

We were unsuccessful in translating our research findings into the L3MTO product completely, however. In particular, although the surveys and interviews revealed that use of the terms “above normal”, “near normal”, and “below normal” consistently lead to confusion and misinterpretation, without clear evidence of the superiority of alternative language, CSD was unwilling to change the product language. The same perspective exists concerning the replacement of “equal chances”, in situations where no skill has been demonstrated by any forecasting technique, with alternative language, e.g., “indeterminate”.

Department of Commerce (DOC) policy limitations prohibited the development of dynamically interactive products as originally conceived for this project. Thus, our efforts to implement dynamic forecast formatting tools shifted to focus on supporting the CSD contractor through periodic reviews of approach and outcomes.

The NWS Climate Prediction Center (CPC) also became interested in the findings from this research project as well. CPC recognized that, in particular, their “Probability of

Exceedance (POE) Maps” (URL: <http://www.cpc.ncep.noaa.gov/products/predictions/90day/lead01/poe.html>). CPC was unable to change the format of map due to an onerous product modification process. Instead, we worked with CPC personnel to adapt the figure caption. Figure 3 shows the current text that was adopted by the CPC. Changes included use of the term ‘mid-value’ instead of ‘normal’, a direct interpretation of the chances of conditions for the season falling both above and below the ‘mid-value’, and a recognition that this product is limited because it does not show the range of possibility of conditions over the upcoming season.

Anomaly (deg F) of the Mid-value of the 3-Month Temperature Outlook Distribution for JFM 2008
Dashed lines are the median 3-month temperature (degrees F) based on observations from 1971–2000. Shaded areas indicate whether the anomaly of the mid-value is positive (red) or negative (blue) compared to the 1971–2000 average. Non-shaded regions indicate that the absolute value of the anomaly of the mid-value is less than 0.1. For a given location, the mid-value of the outlook may be found by adding the anomaly value to the 1971–2000 average. There is an equal 50–50 chance that actual conditions will be above or below the mid-value. Please note that this product is a limited representation of the official forecast, showing the anomaly of the mid-value, but not the width of the range of possibilities. For more comprehensive forecast information, please see our additional forecast products.

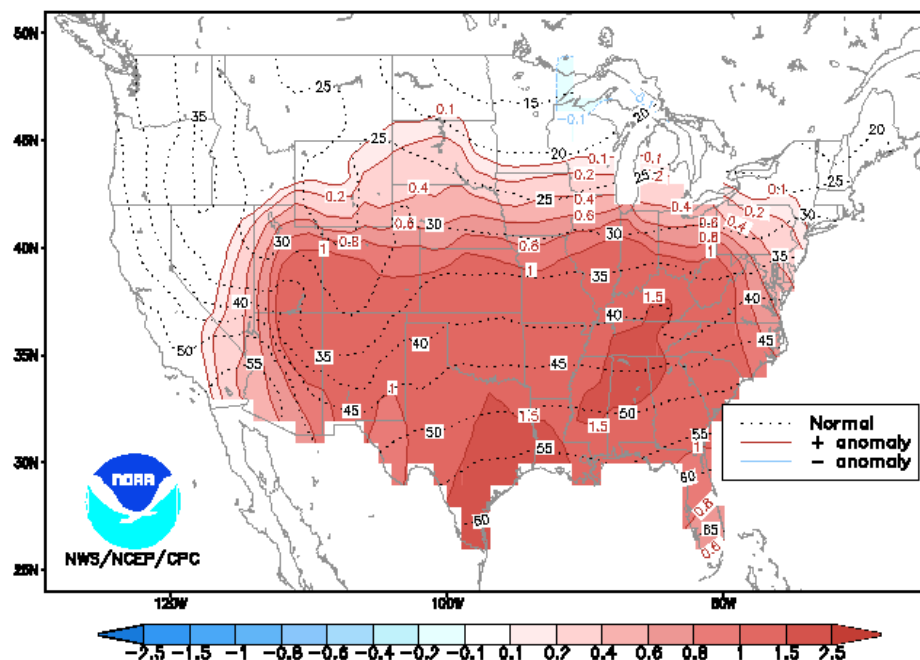


Figure 3. NWS product caption adapted based on project findings.

Based on our research findings and clear applicability to operational NWS products, we submitted a proposal to the NWS Climate Test Bed program to work with the CPC. That project was approved to begin immediately at the end of this one (July 1, 2007). One component of that project is aimed at incorporating the survey- and interview-based field testing of communication effectiveness, pioneered in this project, as a formal part of the CPC product development process.

Key Results:

- Close working relationship with CSD enabled implementation of research findings into experimental forecast products, with potential for becoming operational products.

- The experimental products include multiple formats for communicating forecast information, with the formats designed to reduce common misinterpretation problems.
- Adoption of improved text for the official CPC seasonal climate outlook POE mid-value anomaly map.
- Received funding from the NWS Climate Test Bed program, for a \$433,000 project over 3 years, to work with the CPC. In part, that project will incorporate the survey- and interview-based field testing of communication effectiveness, pioneered here, as a formal part of the CPC product development process. That project is also aimed at shifting federal information technology policy and implementing dynamic forecast formatting capabilities within CPC for their products.

Key Findings:

- DOC policies significantly limit the potential for developing dynamic forecast products with user-controlled formats and interpretation assistance.
- While NWS personnel recognize that use of specific terms leads to misinterpretation of forecast information, they are reluctant to discard terms having a long tradition of use without significant evidence of the clear superiority of alternative language.

Recommendations:

- Adaptation of federal information technology policy is required to enable dynamic forecast format capabilities.

Dynamic Forecast Formatting Tools

In this project, we developed a “proof-of-concept” prototype of a key component of a dynamic forecast formatting tool, now part of the UA Climate Information Delivery and Decision Support System (CLIDDSS). In particular, we were able to develop the databases, interfaces, and integrative software code for allowing an information intermediary or end user to:

- efficiently interact with multiple distributed websites delivering forecast or other information products over time,
- obtain automated retrieval of their preferred forecast product parameters, and
- convert preferred products into flexible PDF format, which facilitates the transfer of the online survey questionnaire and preferred forecast formats to stakeholders without Internet access.

The underlying architecture of CLIDDSS was significantly modified to provide for incorporation of proprietary products without having to incorporate security features that threatened to require all project resources.

We demonstrated a “proof-of-concept” for use of CLIDDSS to develop a high-quality newsletter. The Climate Assessment for the Southwest (CLIMAS) project volunteered to participate in the experiment. They used CLIDDSS in the development of their Spring 2007 Border Climate Summary newsletter and demonstrated that CLIDDSS is effective

for efficiently incorporating external products in newsletter format, with both ‘boiler-plate’ standardized text (e.g., from a product provider) and value-added interpretation.

In part due to the success of CLIDDSS development under this project, we received funding through the Pacific Region Integrated Data Enterprise (PRIDE) program. That project, for approximately \$95,000 over 1 year, is intended to move CLIDDSS development from the “proof-of-concept” goals of this project to stage suitable for application with products generated by external providers.

In addition, based on the successful progress of CLIDDSS development, we were asked by three different Regional Integrated Science and Assessment (RISA) programs to collaborate with them in proposals for submission to the National Integrated Drought Information System (NIDIS) Coping with Drought initiative. The three decision support tools included the Dynamic Drought Index Tool developed by the Carolinas RISA, AgClimate (now AgroClimate) developed by the Southeast Climate Consortium, and tool under development to provide analog analysis of paleostreamflow reconstructions. All three projects were funded.

Key Results:

- Developed and demonstrated “proof-of-concept” implementation of CLIDDSS, a system for managing portfolios of information products from diverse sources and incorporating them into high quality newsletters.
- Changed original design to enable CLIDDSS application for secure use with proprietary information, making the tool suitable for use with products developed by the private sector as well as agencies.
- Demonstrated use of CLIDDSS to develop a high quality newsletter, specifically the Spring 2007 issue of the US/Mexico Border Climate Summary issued by the CLIMAS project at the University of Arizona.
- Generated significant interest among climate information providers and developers of decision support tools to have their products and services connect to CLIDDSS.

Recommendations:

- Continue to pursue development of CLIDDSS and connection of CLIDDSS services with operational products, including decision support tools being developed by other projects funded by the Climate Program Office.

Reporting and Technology Transfer

(* = Invited Presentations, # = International)

Hartmann, H.C. and N. Haas, 2006. Assessment of probabilistic forecasts using field surveys of resource management professionals: preliminary results. Fourth Annual Climate Predication Applications Science Workshop, NWS Climate Services Division, Tucson, AZ, 21-24 March.

- Hartmann, H.C., 2006. A climate information delivery and decision support system. Fourth Annual Climate Prediction Applications Science Workshop, NWS Climate Services Division, Tucson, AZ, 21-24 March.
- *Hartmann, H.C., 2006. Climate and society: working with a nation of stakeholders. Congressional Staff Symposium, From Knowledge to Action: Making Use of Climate Predictions, University Consortium on Climate Research, Washington, DC, 4 May.
- *Hartmann, H.C., 2006. Understanding CPC Seasonal Outlooks. Operational Climate Services Residential Training Courses, National Weather Service, Kansas City, MO, 13-15 June.
- *Hartmann, H.C., 2006. Packaging climate products for users. Climate Diagnostics and Predictions Workshop, NOAA, Boulder, CO, 23-27 October.
- Hartmann, H.C., 2007. Misinterpretation of probabilistic seasonal climate outlooks by resource management professionals. 35th Conference on Broadcast Meteorology/87th Annual Meeting, American Meteorological Society, San Antonio, TX, 15-18 January.
- *Hartmann, H.C., 2007. Climate services and decision support: strategies, tactics and tools. Informal Seminar, Climate Program Office, NOAA, Silver Springs, MD, 15 March.
- *Hartmann, H.C., 2007. Understanding CPC seasonal outlooks. Operational Climate Services Residential Training Courses, National Weather Service, Kansas City, MO, 10-12 April.
- *#Hartmann, H.C., 2007. Tools for climate services. Joint Assembly, American Geophysical Union, Acapulco, Mexico, 22-25 May.
- *#Hartmann, H.C., 2007. The use of climate information for decision making. Workshop on Application of Statistics in Agriculture, Agriculture Canada, Regina, SK, 6-7 June.
- *#Hartmann, H.C., 2007. Climate services and decision support: strategies, tactics, and tools. Informal Seminar, National Land and Water Information System, Agriculture Canada, Regina, SK, 8 June.
- Based in part on the work conducted in this project, H. Hartmann also was invited to serve on a panel on “Decision Making, Partners, and Stakeholders” at the Fourth Annual Climate Prediction Applications Science Workshop, NWS Climate Services Division, Tucson, AZ, 21-24 March 2006.